

# CONTENTS, Exploring Black Holes, Second Edition

**Graphic: Travel to Other Universes**

**Front Cover**

**Constants and Conversion Factors, Questions**

**Inside Front Cover**

## **Chapter 1. Speeding**

Background in special relativity. Invariance; interval; worldline; energy and momentum from the Principle of Maximal Aging; limits on the local inertial frame due to spacetime curvature.

## **Chapter 2. The Bridge: SR to GR**

Curvature of Earth's surface as an analog to curvature of spacetime. Local and global metrics for both space and spacetime. Flat Kansas on curved Earth as analog to the local inertial frame in curved spacetime. The difference between space and spacetime. Goodbye "distance," goodbye "time."

## **Chapter 3. Curving**

Describe curved spacetime outside Earth and down to the center of a non-spinning black hole. Global coordinates and the Schwarzschild global map of events. One-way event horizon.

## **Chapter 4. The Global Positioning System (GPS)**

Locate yourself anywhere on Earth with a hand-held device whose operation depends crucially on general relativity.

## **Chapter 5. Global and Local Metrics**

The global metric describes curved spacetime with global "map" coordinates that we choose arbitrarily. Over a small enough spacetime patch, curved spacetime is effectively flat, so special relativity applies. Our rule: Describe every experiment and observation in a local inertial frame.

## **Chapter 6. Diving**

Dive into a black hole. How fast do you move? How do you feel? How long do you live? Global map energy as a constant of motion from the Principle of Maximal Aging. Local rain frame. Local gravitational acceleration.

## **Chapter 7. Inside the Black Hole**

A relaxed life with spectacular effects behind and ahead of you, and an ending certain. Global rain coordinates. Global metric as sum and difference of squares.

## **Chapter 8. Circular Orbits**

Map angular momentum as a constant of motion. Your spaceship rides in a circular "parking orbit" around a black hole. Predict this orbit at a glance.

## **Chapter 9. Orbiting**

Insert your spaceship into a circular orbit. Transfer between circular orbits. Look out! Killer tides threaten humans and robots.

## **Chapter 10. Advance of Mercury's Perihelion**

An early victory of Einstein's brand new general relativity theory.

## **Chapter 11. Orbits of Light**

Trajectories of light around a black hole. Predict these orbits at a glance. Which light beams connect that star with this observer?

## **Chapter 12. Diving Panoramas**

A diver rides her local rain frame to the center of a black hole. What changing panoramas surround her? What is the last thing she sees?

## **Chapter 13. Gravitational Mirages**

Stars, galaxies, and black holes act like distorting lenses that magnify distant structures and help us to take a census of mass in the Universe. Einstein's surprise: Space curvature affects the bending of light rays.

## **Chapter 14. Expanding Universe**

The shape in space and time of an expanding Universe derived from signals emitted by stars and galaxies in the past. The Friedmann-Robertson-Walker global metric. Constant of galaxy motion from Principle of Maximal Aging.

## **Chapter 15. Cosmology**

Composition of the Universe: ordinary matter, dark matter, and dark energy. Development of the Universe since the Big Bang. Alternative cosmic futures.

## **Chapter 16. Gravitational Waves**

Ripples in spacetime described by a time-dependent global metric. Measurements in a local inertial Earth frame. Gravitational waves from binary black holes. LIGO.

## **Chapter 17. Spinning Black Hole**

Global structure of the spinning black hole: irresistible motion, two horizons, map energy, map angular momentum, and the raindrop. Local rain, static, and ring observers.

## **Chapter 18. Circular Orbits around the Spinning Black Hole**

Circular orbits outside and—strangely—inside the event horizon. Accretion disks power quasars.

## **Chapter 19. Orbiting the Spinning Black Hole**

Insert your spaceship into a circular orbit around the spinning black hole. Transfer a probe from one circular orbit to smaller ones. Penrose process. Killer tides again threaten humans and robots.

## **Chapter 20. Orbits of Light around the Spinning Black Hole**

What do we see as we orbit around and plunge into the spinning black hole?

## **Chapter 21. Leaving Our Universe**

Where can maneuvers inside the spinning black hole allow us to travel? Can we return?

## **Appendix A: Wheeler's Rules**

Motivate! Simplify! Self-descriptive terminology, the dullness of simply being, and other rules of writing.

## **Appendix B: Glossary**

Where to find the definitions of terms. List of words not used in this book.

## **General Relativity Briefing**

**Inside Back Cover**

## **Graphic: Organization of Topics**

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